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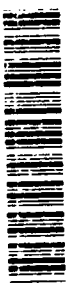

13. ABSTRACT *(Maximum 200 words)*

This is the final technical report on the project "Advanced Parallel Systems". The objective of this project was to explore algorithms and their implementation for future advanced parallel systems. These systems are assumed to have hundreds or even thousands of processors and to be able to concentrate their computing power on one or a small number of tasks. Three principal questions were explored (a) Are there algorithms for the crucial applications which have enough parallelism to allow the power of the advanced parallel systems to be fully exploited? (b) What languages and implementation tools are needed for efficient programming of the algorithms? (c) What are the relative performances of different algorithm types? Of different architecture types? Of different implementation languages? We state the principal problem for four areas and then list the papers, conference presentations, theses and technical reports for each area:

1. Analysis of the Performance of Future Computations
2. Benchmarking Existing Computations
3. Control of Parallel Computations
4. Parallel Algorithms for Physical Problems

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FINAL TECHNICAL REPORT

DAAL03-90-G-0107
Research Sponsored by SDIO/IST and managed by ARO

ADVANCED PARALLEL SYSTEMS

John R. Rice
August 21, 1992

This report covers the activities of John R. Rice (Co-PI) and associates at Purdue University from May 1990 through September 30, 1991. The three year funding was terminated early and work stopped by September 30, 1991 (as all funds had been spent). The accomplishments include 7 papers published in or submitted to technical journals, 10 conference presentations with papers in the conference proceedings, 3 other technical reports, and two Ph.D. theses.

The objective of this work was to explore algorithms and their implementation for future advanced parallel systems. These systems are assumed to have hundreds or even thousands of processors and to be able to concentrate their computing power on one or a small number of tasks. The three principal questions to be explored were:

1. Are there algorithms for the crucial applications which have enough parallelism to allow the power of the advanced parallel systems to be fully exploited?
2. What languages and implementation tools are needed for efficient programming of these algorithms?
3. What are the relative performances of different algorithm types? Of different architecture types? Of different implementation languages?

The research results obtained are grouped within four areas, basically those described in the original proposal. We state the principal problem for each area and then list the papers, conference presentations, theses and technical reports for each area, followed by a short summary of principal or typical results obtained.

A. ANALYSIS OF THE PERFORMANCE OF FUTURE COMPUTATIONS

Principal Problem: Analyze the practicality of using massive parallelism efficiently in large scale scientific and engineering computations.

1. **D.C. Marinescu and J.R. Rice**, Synchronization and load imbalance effects in distributed memory multi-processor systems, *Concurrency Practice and Experience* 3, (1991), 593–625.
2. **D.C. Marinescu and J.R. Rice**, On high level characterization of parallelism, *J. Par. Dist. Comp.*, (1993), to appear.

3. **D.C. Marinescu and J.R. Rice**, The effects of communication and latency on synchronization and dynamic load balance on a hypercube, *Proc. 5th Intl. Parallel Processing Symposium*, (Kumar, ed.), IEEE Press, (1991), 18–25.

4. **D.C. Marinescu, C.E. Houstis, J.R. Rice, H. Waldschmidt, and B. Waltshurper**, Distributed supercomputing, in *Future Trends '90*, IEEE P: (1990), 381–387.

5. **Jin Jing and J.R. Rice**, Problems to test parallel and vector languages - II, CSD-TR 1016, Purdue University, CS Department, December 1990.

B. BENCHMARKING EXISTING COMPUTATIONS

Principal Problem: Analyze the performance of existing parallel software and machines. Develop methodology for benchmarking the performance of scientific and engineering software.

6. **D.C. Marinescu, J.R. Rice, and E.A. Vavalis**, Performance of iterative methods for distributed memory machines, *Applied Numerical Mathematics* (1993), to appear. Extended abstract in *Proc. 13th World Congress*, IMACS, Rutgers University, New Brunswick, NJ, Vol. 2 (1991), 684–685.

7. **Mo Mu and J.R. Rice**, Performance of PDE sparse solvers on hypercubes, in *Unstructured Scientific Computations on Scalable Multiprocessors* (J. Saltz, ed.), MIT Press (1992), 345–370.

8. **Mo Mu and J.R. Rice**, A PDE sparse solver benchmark for massively parallel distributed memory multiprocessors, in *Computer Methods for Partial Differential Equations VII* (R. Vichnevetsky, ed.), IMACS, New Brunswick, NJ (1992).

C. CONTROL OF PARALLEL COMPUTATIONS

Principal Problem: Determine how to break computations into nearly equally sized pieces to distribute to a collection of processors. Determine how parallel processors can synchronize and organize their work so as to avoid or minimize bottlenecks.

9. **E.N. Houstis, S.K. Kortesis, and H. Byun**, A workload partitioning strategy for PDEs by a generalized neural network. CSD-TR-934, Computer Science Department, Purdue University (1990).

10. **N.P. Chrisochoides, C.E. Houstis, and E.N. Houstis**, Geometry based mapping strategies for PDE computations. In *Supercomputing 91*, ACM Press, NY (1991), 115–127.

11. **Mo Mu and J.R. Rice**, A grid based subtree-subcube assignment strategy for solving PDEs on hypercubes, *SIAM J. Sci. Stat. Comp.*, **13** (1992), 826–839.

12. **N.P. Chrisochoides, C.E. Houstis, E.N. Houstis, S.K. Kortesis, P.N. Papachiou and J.R. Rice**, Domain decomposer: A software tool for mapping PDE computations to parallel architectures. In *Domain Decomposition Methods for Partial Differential Equations*, SIAM (1991), 341–357.

13. **E.N. Houstis and J.R. Rice**, Parallel ELLPACK: A development and problem solving environment for high performance computing machines. In *Programming Environments for High-Level Scientific Problem Solving* (P. Gaffney and E. Houstis, eds.), North-Holland, Amsterdam (1992), 229–241.

14. **N.P. Chrisochoides and J.R. Rice**, Partitioning heuristics for PDE computations based on parallel hardware and geometry characteristics. In *Computer Methods for Partial Differential Equations VII* (R. Vichnevetsky, ed.), IMACS, New Brunswick, NJ (1992).

15. **N.P. Chrisochoides**, *On the Mapping of Partial Differential Equations onto Distributed Memory MIMD Parallel Machines*, Department of Computer Sciences, Purdue University, Ph.D. Thesis (1992).

D. PARALLEL ALGORITHMS FOR PHYSICAL PROBLEMS

Principal Problem: Create algorithms that are easily broken into parallel subcomputations and whose total work is near the minimum possible.

16. **M. Aboelaze, N.P. Chrisochoides, E.N. Houstis, and C.E. Houstis**, Parallelization of level 2 and 3 BLAS operations on distributed memory machines, CAPO report CER-91-04, Computer Sciences, Purdue University, 1991.

17. **A. Chen and J.R. Rice**, On grid refinement at point singularities for h-p methods, *Intl. J. Num. Meth. Engr.*, **33**, (1992), 39–57.

18. **Mo Mu and J.R. Rice**, Row oriented Gauss elimination on distributed memory multiprocessors, *Intl. J. High Speed Comp.* (1993), to appear.

19. **A. Hadjidimos, E.N. Houstis, J.R. Rice, and E.A. Vavalis**, Iterative line cubic spline collocation methods for elliptic partial differential equations in several dimensions, *SIAM J. Sci. Stat. Comp.* (1993), to appear.

20. **H.S. McFaddin and J.R. Rice**, RELAX: A platform for software relaxation. In *Expert Systems for Scientific Computing* (Houstis, Rice, and Vichnevetsky, eds.), North-Holland, Amsterdam (1992), 175–194.

21. **N.P. Chrisochoides, E.N. Houstis, S.B. Kim, J.R. Rice, and M.K. Samartzis**, Parallel iterative methods. In *Computer Methods for Partial Differential Equations VII* (R. Vichnevetsky, ed.), IMACS, New Brunswick, NJ (1992).

22. **H.S. McFaddin**, *An Object Based Problem Solving Environment for Collaborating PDE Solvers and Editors*, Department of Computer Sciences, Purdue University, Ph.D. Thesis (1992).

E. PERSONNEL

The principal personnel were:

John R. Rice	Professor of Computer Science
Elias N. Houstis	Professor of Computer Science
Dan C. Marinescu	Associate Professor of Computer Science

They were assisted by the faculty, post-docs and graduate students listed below. Some of these were supported by teaching or fellowships as well as by this project.

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S.B. Kim	Ph.D. candidate
S.K. Kortesis	Visiting Scholar
H.S. McFaddin	Ph.D. graduate
Mu Mo	Post-doc
P. Papachiou	M.S. graduate
M. Samartzis	M.S. graduate
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